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(54) Improved tools for percussive and rotary crushing rock drilling provided with a diamond layer

Werkzeuge für Dreh- und Schlagbohren mit einer Diamantschicht

Outils perfectionnés pour forage rotatif et à percussion de roche avec une couche en diamant

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US-A- 4 743 515
US-A- 4 764 434

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Description

The present invention concerns the field of rock bits and buttons therefor. More particularly the invention relates to rock bit buttons for percussive and rotary crushing rock drilling. The buttons comprise cemented carbide provided with a diamond layer bonded by HP/HT technique.

BACKGROUND OF THE INVENTION

EP-A-0322214 discloses a cemented carbide rock bit button for percussive and rotary crushing rock drilling, at least partly covered with a diamond layer bonded at high pressure and high temperature.

There are three main groups of rock drilling methods: percussive, rotary crushing and cutting rock drilling. In percussive and rotary crushing rock drilling the bit buttons are working as rock crushing tools as opposed to cutting rock drilling, where the inserts work rather as cutting elements. A rock drill bit generally consists of a body of steel which is provided with a number of inserts comprising cemented carbide. Many different types of such rock bits exist having different shapes of the body of steel and of the inserts of cemented carbide as well as different numbers and grades of the inserts.

For percussive and rotary crushing rock drilling the inserts often have a rounded shape, generally of a cylinder with a rounded top surface generally referred to as a button. For cutting rock drilling the inserts are provided with an edge acting as a cutter.

There already exists a number of different high pressure-high temperature sintered cutters provided with polycrystalline diamond layers. These high wear resistant cutter tools are mainly used for oil drilling.

The technique when producing such polycrystalline diamond tools using high pressure-high temperature (HP/HT) has been described in a number of patents, e.g.:

US Patent No 2,941,248: "High temperature high pressure apparatus".

US Patent No 3,141,746: "Diamond compact abrasive".

High pressure bonded body having more than 50 vol% diamond and a metal binder:Co,Ni,Ti,Cr,Mn,Ta etc.

These patents disclose the use of a pressure and a temperature where diamond is the stable phase.

In some later patents: e.g. US Patent Nos 4,764,434 and 4,766,040 high pressure-high temperature sintered polycristalline diamond tools are described. In the first patent the diamond layer is bonded to a support body having a complex, non-plane geometry by means of a thin layer of a refractory material applied by PVD or CVD technique.

In the second patent temperature resistant abrasive polycrystalline diamond bodies are described having different additions of binder metals at different distances from the working surface.

A recent development in this field is the use of one or more continuous layers of polycrystalline diamond on the top surface of the cemented carbide button.

US Patent 4,811,801 discloses rock bit buttons including such a polycrystalline diamond surface on top of the cemented carbide buttons having a Young's modulus of elasticity between 80 and 102 x 10^6 p.s.i., a coefficient of thermal expansion between 2,5 and 3,4 x 10^{-6} °C $^{-1}$, a hardness between 88,1 and 91,1 HRA and a coercivity between 85 and 160 Oe. Another development is disclosed in US Patent 4,592,433 including a cutting blank for use on a drill bit comprising a substrate of a hard material having a cutting surface with strips of polycrystalline diamond dispersed in grooves, arranged in various patterns.

US Patent 4,784,023 discloses a cutting element comprising a stud and a composite bonded thereto.

The composite comprises a substrate formed of cemented carbide and a diamond layer bonded to the substrate. The interface between the diamond layer and the substrate is defined by alternating ridges of diamond and cemented carbide which are mutually interlocked. The top surface of the diamond body is continuous and covering the whole insert. The sides of the diamond body are not in direct contact with any cemented carbide.

Another development in this field is the use of cemented carbide bodies having different structures in different distances from the surface.

US Patent 4,743,515 discloses rock bit buttons of cemented carbide containing eta-phase surrounded by a surface zone of cemented carbide free of eta-phase and having a low content of cobalt in the surface and a higher content of cobalt closer to the eta-phase zone.

US Patent 4,820,482 discloses rock bit buttons of cemented carbide having a content of binder phase in the surface that is lower and in the center higher than the nominal content. In the center there is a zone having a uniform content of binder phase. The tungsten carbide grain size is uniform throughout the body.

OBJECT OF THE INVENTION

The object of the invention is to provide a rock bit button of cemented carbide with a diamond layer with high and uniform compression of the diamond layer by sintering at high pressure and high temperature in the diamond stable area.

It is a further object of the invention to make it possible to maximize the effect of diamond on the resistance to cracking and chipping and to wear.

SUMMARY OF THE INVENTION

According to the present invention there is provided a rock bit button for percussive and rotary crushing rock drilling comprising a body of cemented carbide, according to US Patent 4,743,515, provided with a diamond layer and produced at high pressure and high temperature.

The button above can be adapted to different types of rocks by changing the material properties and geometries of the cemented carbide and/or the diamond, especially hardness, elasticity and thermal expansion, giving different wear resistance and impact strengh of the button bits.

Percussive rock drilling tests using buttons of the type described in US Patent 4,811,801 with continuous polycrystalline layers on the surface of cemented carbide revealed a tendency of cracking and chipping off part of the diamond layer.

When using a cemented carbide body having a multi-structure according to US Patent 4,743,515 with a diamond layer, FIG.6, it was surprisingly found that the cracking and chipping tendency of the diamond layer considerably decreased.

The explanation for this effect, the increase of the resistance against cracking and chipping, might be a favourable stress pattern caused by the difference between the thermal expansion of the diamond layer and the cemented carbide body, giving the layer a high and uniform compressive prestress.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be described with reference to the accompanying drawings in which

1 = cemented carbide button
2 = steel body
3 = diamond layer or body
4 = cemended carbide : Co poor zone
5 = cemented carbide : Co rich zone
6 = cemented carbide : eta-phase containing core

FIG.1 shows a standard bit for percussive rock drilling provided with cemented carbide buttons.

FIG.2 shows a standard bit for rotary crushing rock drilling provided with cemented carbide buttons.

FIG.3 shows a standard cemented carbide button without diamond.

FIG.4 shows a button where the cemented carbide is containing eta-phase surrounded by a surface zone of cemented carbide free of eta-phase.

FIG.5 shows a button of cemented carbide with a top layer of diamond.

FIG.6 shows a button of cemented carbide with a top layer of diamond where the cemented carbide is containing eta-phase surrounded by a surface zone of cemented carbide free of eta-phase.

FIG.7-14 show buttons of cemented carbide with a top layer of diamond and different types of diamond bodies beneath the top layer and inside the body of cemented carbide. The core of the cemented carbide body is containing eta-phase surrounded by a surface zone of cemented carbide free of eta-phase.

DETAILED DESCRIPTION OF THE INVENTION.

The rock bit button according to the present invention comprises a cemented carbide body according to US Patent 4,743,515 and is provided with one or more polycrystalline diamond layers produced by HP/HT technique. The diamond layer can be of various shapes such as a completely or partly covered layer on top of the body of cemented carbide.

For special applications the diamond on the convex carbide surface may be attached in rings or spirals.

Independent of the shape the surface length of the diamond layer shall be more than 1 mm, preferably more than 2 mm and the thickness more than 0.2 mm, preferably 0,4-2,0 mm. The area of the layer of polycrystalline diamond should be more than 10%, preferably more than 50% of the top surface.

The rock bit button shall have a diameter of 5-50 mm preferably 7-35 mm. Other shapes than cylindrical are also possible such as chisel shaped,spherical,oval or conical. Other more asymmetric shapes could also be used such as rectangular, pyramids or square pyramids.

The polycrystalline diamond layer shall be adapted to the type of rock and drilling method by varying the grain size of the diamond and the amount of binder metal.

The grain size of the diamond shall be 3-300 micrometer, preferably 35-150 micrometer. The diamond may be of only one nominal grain size or consist of a mixture of sizes. such as 80 w/o of 40 micrometer and 20 w/o of 10 micrometer.

Different types of binder metals can be used such as Co,Ni,Mo,Ti,Zr,W,Si,Ta,Fe,Cr,Al,Mg,Cu,etc. or alloys between them. The amount of binder metal shall be 1-40 vol.%, preferably 3-20 vol.%.

In addition other hard materials, preferably less than 50 vol.%, can be added such as: cBN, B_4C, TiB_2, SiC, ZrC, WC, TiN, ZrB, ZrN. TiC, (Ta.Nb)C, Cr-carbides, AlN, Si_3N_4, AlB_2 etc. as well as whiskers of B_4C, SiC, TiN, Si_3N_4, etc. (See US Patent 4,766,040).

The layer of polycrystalline diamond may have different levels of binder metal at different distances from the working surface according to US Patent 4,766,040.

The cemented carbide grade shall be chosen with respect to type of rock and drilling methods. It is important to chose a grade which has a suitable wear resistance compared to that of the polycrystalline diamond body. The nominal binder phase content shall be 3-35 weight %, preferably 5-12 weight % for percussive and preferably 5-25 weight % for rotary crushing rock drilling buttons and the grain size of the cemented carbide at least 1 micrometer, preferably 2-6 micrometer.

The cemented carbide body shall have a core containing eta-phase. The size of this core shall be 10-95%, preferably 30-65% of the total amount of cemented carbide in the body.

The core should contain at least 2% by volume, preferably at least 10% by volume of eta-phase but at most 60% by volume, preferably at the most 35% by volume.

In the zone free of eta-phase the content of binder phase, i.e. in general the content of cobalt, shall in the surface be 0,1-0,9, preferably 0,2-0,7 of the nominal content of binder phase and the binder phase content shall increase in the direction towards the core up to a maximum of at least 1,2 , preferably 1,4-2,5 of the nominal content of binder phase. The width of the zone poor of binder phase shall be 0,2-0,8 , preferably 0,3-0,7 of the width of the zone free of eta-phase, but at least 0,4 mm and preferably at least 0,8mm in width.

The bodies of polycrystalline diamond may extend a shorter or longer distance into the cemented carbide body.

In one embodiment the polycrystalline diamond layer consists of a prefabricated and sintered layer in which the binder metal has been extracted by acids.

The layer is attached by the HP/HT technique.

This method gives a favourable stress distribution and a better thermal stability because of the absence of the binder metal.

In another embodiment the cemented carbide substrate has been provided with diamond bodies of different shapes according to US Patent Application 07/511,096 beneath the top layer of diamond.

The cemented carbide buttons are manufactured by powder metallurgical methods according to US Patent 4,743,515. After sintering of the cemented carbide the mixture of diamond powder, binder metal and other ingredients is put on the surface of the cemented carbide body,enclosed in thin foils and sintered at high pressure, more than 3,5 GPa, preferably at 6-7 GPa, and at a temperature of more than 1100°C ,preferably 1700°C for 1-30 minutes, preferably about 3 minutes.

The content of catalyst metal in the diamond layer may be controlled either by coating the button before applying the diamond layer with a thin layer of e.g. TiN by CVD- or PVD-methods or by using thin foils such as Mo as disclosed in US Patent 4,764,434.

After high-pressure sintering the button is blasted and ground to final shape and dimension.

The description above concerns diamond and the HP/HT technique of bonding but the same principles are also valid for cBN.

EXAMPLE 1

PERCUSSIVE ROCK DRILLING

In a test in a quartzite quarry the penetration rate and the life length of the bits with buttons having a multi-phase structure of the cemented carbide and a layer of polycrystalline diamond according to the invention were compared to bits with buttons of conventional cemented carbide, with buttons having a multi-phase structure and with bits with a layer of polycrystalline diamond and having a conventional structure of the cemented carbide.

All buttons in a bit had the same composition.

The drill hit having 6 buttons on the periphery was a bit with a special and strong construction for use in very hard rocks. (FIG.1).

Bit A. (FIG.3) All buttons on the periphery consisted of cemented carbide with 6 weight % cobalt and 94 weight % WC having a grain size of 2 micrometer. The hardness was 1450 HV3.

Bit B. (FIG.4) All buttons on the periphery consisted of cemented carbide having a core that contained eta-phase surrounded by a surface zone of cemented carbide free of eta-phase having a low content of cobalt (3 weight %) at the surface and said Co-content increasing towards the eta-phase core to a maximum of 11 %.

Bit C. (FIG.5) All buttons on the periphery consisted of cemented carbide having a continuous 0,7 mm thick top layer of polycrystalline diamond.

Bit D. (FIG.6) All buttons on the periphery consisted of cemented carbide having a multi-phase structure and a continuous 0,7 mm thick layer of polycrystalline diamond on top of the body of cemented carbide.

The buttons of cemented carbide had a core that contained eta-phase surrounded by a surface zone of cemented carbide free of eta-phase having a low content of cobalt (3 weight%) at the surface and said Co-content increasing towards the eta-phase core to a maximum of 11%.

The test data were:

Application: Bench drilling in very abrasive quarzite
Rock drilling : COP 1036
Drilling rigg: ROC 712
Impact pressure: 190 bar

Stroke position: 3

Feed pressure: 70-80 bar
Rotation pressure: 60 bar
Rotation: 120 r.p.m.
Air pressure: 4,5 bar
Hole depth: 6-18 m

RESULTS

Type of button	No of bits	Ave life m	Average penetration m per min.
A (FIG. 3)	6	111	1,1
B (FIG. 4)	6	180	1,2
C (FIG. 5)	6	280	1,3
D (FIG. 6)	6	350	1,4

EXAMPLE 2

ROTARY CRUSHING ROCK DRILLING

In an open-cut iron ore mine buttons according to the invention were tested in roller bits.The roller bits were of the type 12 1/4" CH with totally 261 spherical buttons.

The diameter of the buttons was 14 mm on row 1-3 and 12 mm on row 4-6.(FIG.2) .

The same type of buttons : A,B,C and D were used in EXAMPLE 2 as in EXAMPLE 1 except that the cemented carbide had 10 w/o cobalt and 90 w/o WC and a hardness of 1200 HV3.

The test buttons, 77 pcs, were placed in row 1. The remaining buttons were of the standard type.

The performance in form of life time and penetration rate was measured. The drilling data were the following:

Drill rig:	4 pcs BE 60 R
Feed pressure:	60000-80000 lbs
RPM	60
Bench height:	15 m

Hole depth: 17 m

Rock formation: Iron ore : very hard rock

RESULTS

Type of button	No of bits	Aver. life m	Aver. penetration m/hr.
A (FIG. 3)	1	1400	15
B (FIG. 4)	1	1700	16
C (FIG. 5)	1	1900	17
D (FIG. 6)	1	2200	20

Claims

1. Cemented carbide rock bit button (1) for percussive and rotary crushing rock drilling at least partly covered with diamond (3) bonded at high pressure and high temperature, at which said button has a multi-phase structure with a core (6) containing eta-phase surrounded by a surface zone (4,5) free of eta-phase,
where in said button contains at least one diamond body beneath a diamond layer.

Patentansprüche

1. Sintercarbid-Gesteinsmeißelknopf (1) für Schlag- und Drehbohren von Gestein, der wenigstens teilweise mit Diamant (3) bedeckt ist, welcher mit hohem Druck und hoher Temperatur verbunden wurde, wobei dieser Knopf eine Mehrphasenstruktur mit einem eta-Phase enthaltenden Kern (6) hat, der von einer Oberflächenzone (4, 5) frei von eta-Phase umgeben ist, und wobei dieser Knopf wenigstens einen Diamantkörper unter einer Diamantschicht enthält.

Revendications

1. Pointe de trépan de roche à mises rapportées en carbure (1) destinée au forage de roche par écrasement rotatif et écrasement à percussion recouverte au moins partiellement de diamant (3) lié à haute pression et à haute température, auxquelles ladite pointe a une structure multiphasique avec un noyau (6) contenant de l'êta - phase entourée d'une zone superficielle (4, 5) dépourvue d'êta - phase, où ladite pointe contient au moins un corps de diamant en dessous d'une couche de diamant.

FIG. 1

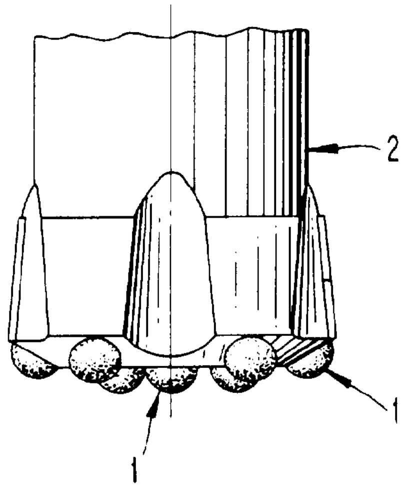
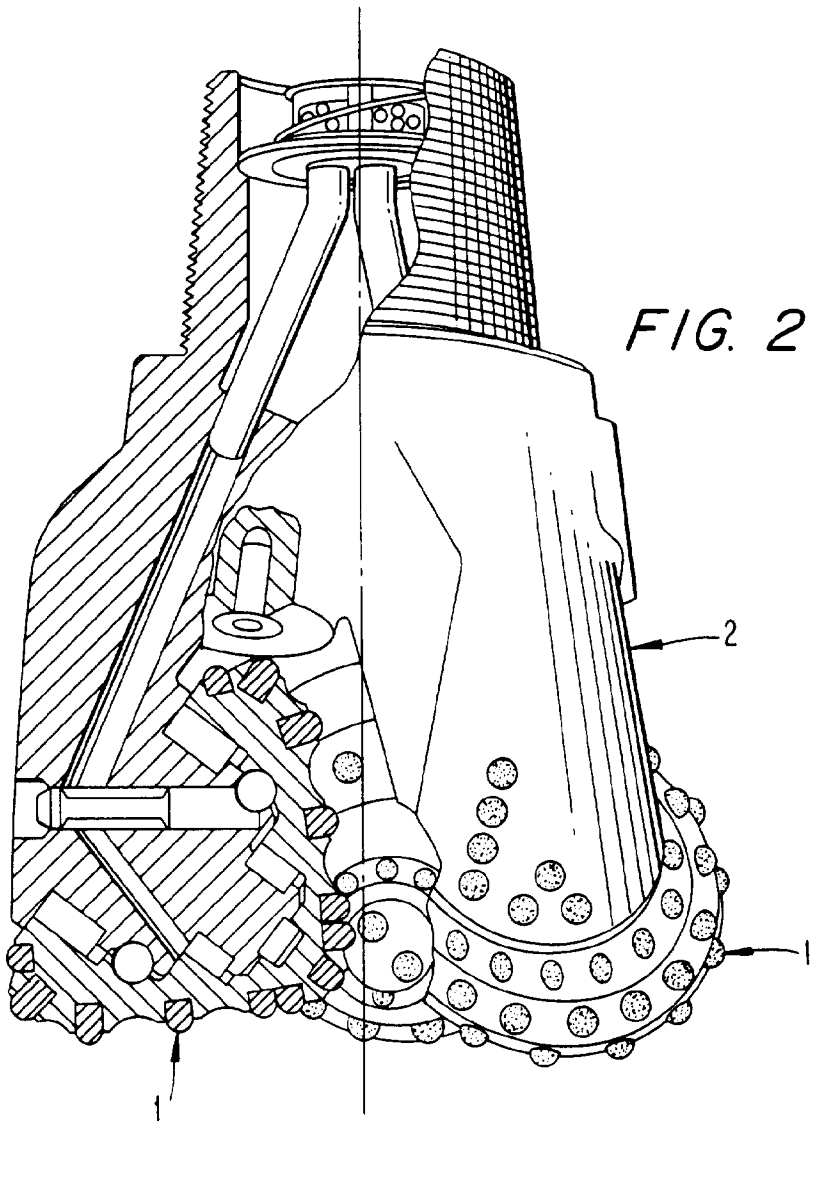


FIG. 2



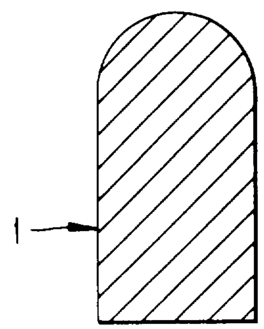


FIG. 3

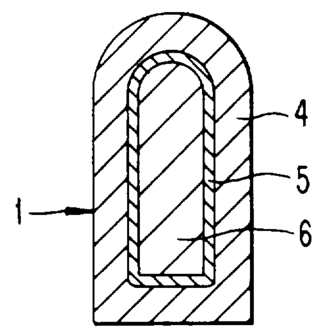


FIG. 4

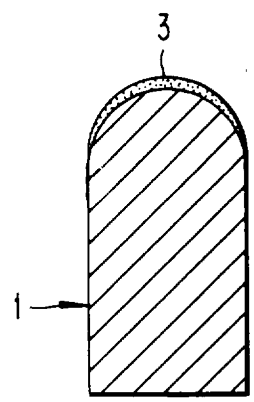


FIG. 5

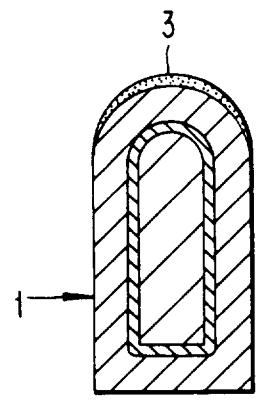


FIG. 6

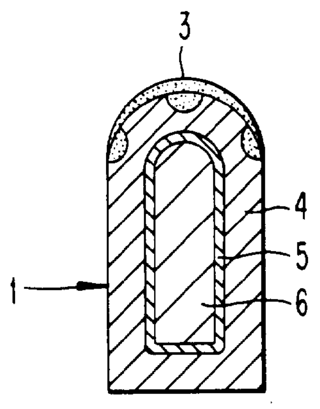


FIG. 7A

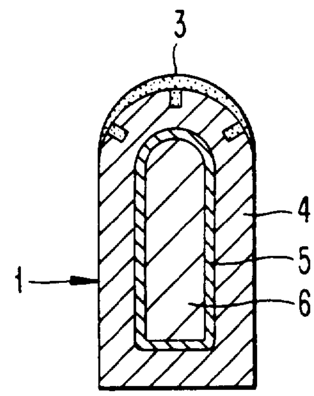


FIG. 8A

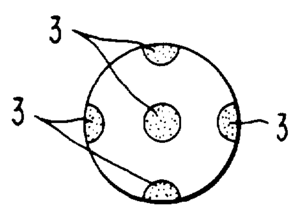


FIG. 7B

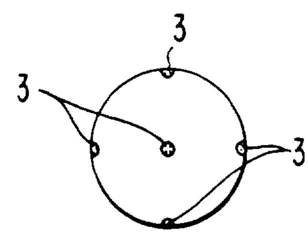


FIG. 8B

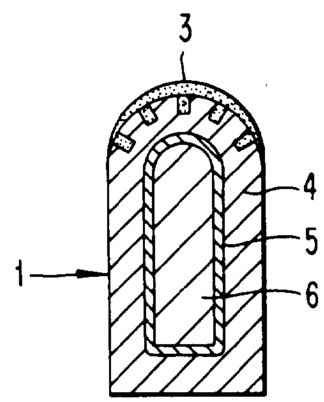


FIG. 9A

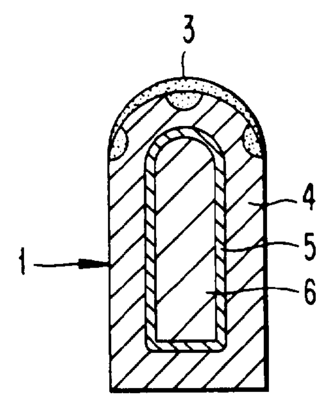


FIG. 10A

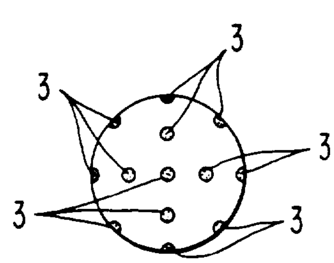


FIG. 9B

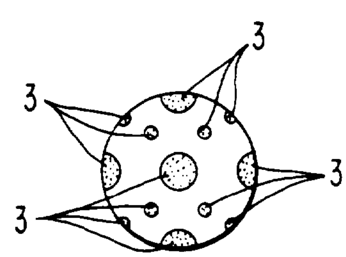


FIG. 10B

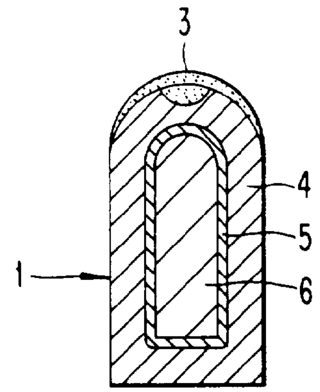


FIG. 11A

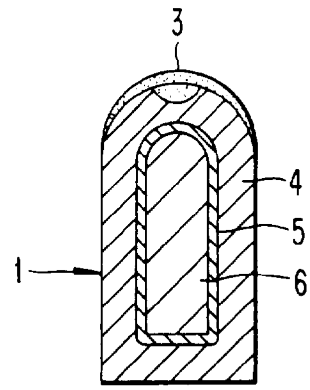


FIG. 12A

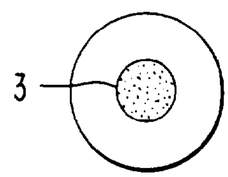


FIG. 11B

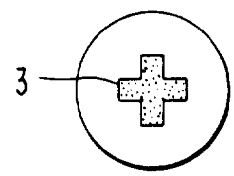


FIG. 12B

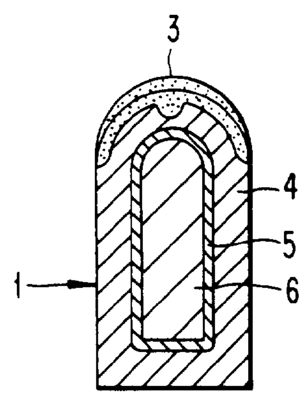


FIG. 13A

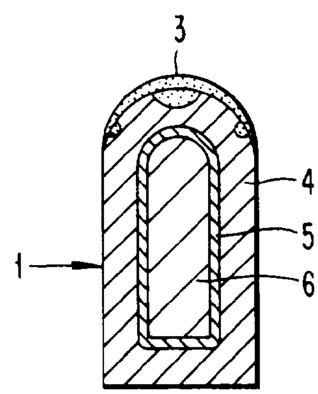


FIG. 14A

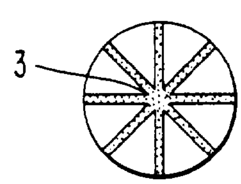


FIG. 13B

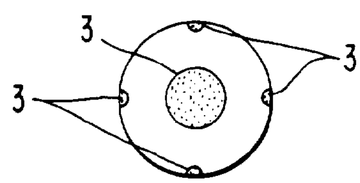


FIG. 14B